increased from −0.42/−0.28 to −0.74 for a one- vs. four year observation period. When not including a common time points in the analysis, correlations of short- and long-term changes were weak to moderate. The application of the SDC approach showed a moderate consistency between the knees identified as progressors over short- and long-term periods. Longer observation periods may therefore be preferable to achieve robust results in individual knees.

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FEASIBILITY OF BONE DENSITY EVALUATION USING PLAIN DIGITAL RADIOGRAPHY

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Purpose: For the evaluation of subchondral bone density (BD) changes due to OA, Dual Energy X-ray Absorptiometry (DEXA) is the most validated method. The need for DEXA might be reduced if the quantitative measurement of clinically relevant BD changes on radiographs is proved feasible, since radiographs are commonly acquired to evaluate structural changes due to OA. Precision of BD evaluation might be influenced by variations in acquisition settings that commonly occur in clinical practice and by post-processing (PP) that was introduced with the transition from conventional film-screen radiography to digital radiography. The objective of this study was to evaluate the effects of PP and acquisition settings on the precision and with that feasibility of BD measurement using plain digital radiography.

Methods: A bone density standard (BDS) was created consisting of eight cups with hydroxyapatite (HA: range 1.0–5.75 g/cm^2). Digital radiographs of the BDS were taken (Philips Digital Diagnost), with variations in the acquisition and PP settings. Tube voltage (in kilovolt: kV), exposure (in milliampere seconds: mAs), tube added filtering, and BDS position in the field-of-view were systematically varied and the default clinical PP was compared with minimal PP (at minimal strength). An aluminum step wedge served as an internal reference to express gray values of the BDS in mm aluminum equivalents (mmAl), by use of custom made software. In all cases a human (cadaver) knee joint was added to simulate clinical conditions. The relation (R^2) between the BD values normalized to the reference wedge (in mmAl equivalents) and actual BD (HA in g/cm^2), with variations in acquisition and PP settings was evaluated with linear regression analyses. Precision of BD measurement of the BDS was calculated in early OA (Cohort Hip & Cohort Knee: CHECK) to evaluate the relevance for clinical (research) practice.

Results: The BDS was validated by DEXA scanning and the relation between actual HA (g/cm^2) and DEXA values was strongly linear: R^2=0.99. In general for digital radiographs a strong correlation between actual BD and BD in mmAl was found for all settings. The correlation improved by changing PP from clinical (R^2=0.96) to minimal (R^2=0.98). Higher kV improved the correlation further. Even, for clinical PP mean SD was 0.97 mmAl, much smaller than the change of 2.51 mmAl clinically observed during two-year follow-up in early OA which implies the feasibility of BD measurements using plain digital radiography.

Conclusions: Accurate bone density measurement using digital radiography is feasible in a clinically relevant range, which removes the need for additional DEXA scans since plain radiographs are acquired for to evaluate structural changes due to osteoarthritis. Care should be taken in changing post-processing and acquisition settings, which can have profound effect on outcome.

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THE OCCURRENCE OF CAM IMPINGEMENT IN YOUNG MALE SOCCER PLAYERS

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Purpose: Femoroacetabular Impingement (FAI) is a cause of hip pain and might cause osteoarthritis (OA) of the hip due to abnormal contact between the femoral neck and acetabulum. Cam impingement is a subtype of FAI, in which the abnormal contact is caused by a cam-type deformity in the femoral head-neck junction. Cam impingement is mostly seen in young active males. However, no studies have focused on the presence of cam-type deformities during skeletal development. This study aimed to determine the age of onset and prevalence of cam-type deformities in young male soccer players versus non-athletic controls.

Methods: 89 elite pre-professional soccer players and 90 controls aged 12–19 years were included in this study. In the soccer players group, both an anteroposterior (AP) and a Lauenstein radiograph of the hip were obtained according to a standardized protocol. Controls with both an AP and a Lauenstein radiograph with no signs of hip pathology were obtained from radiology databases. The alpha angle was calculated in all radiographs using semi-automatized software. An alpha angle larger than 60° was considered to define a cam-type deformity. All radiographs were scored by an orthopedic surgeon and a radiologist, using a three-point scoring system. The anterosuperior head-neck junction was classified as normal (1), flattened (2) or having a prominence (3). The soccer players completed a questionnaire, and range of motion (ROM) and impingement tests were performed. Differences in prevalence were tested using logistic regression, corrected for age. Differences between the mean alpha angle in soccer players and the control group, and differences in the ROM between cam-type deformity cases and normal soccer players were tested using Generalized Estimating Equations, corrected for age.

Results: The mean age was 14.8 years for the soccer players and 13.7 years for the controls. An alpha angle >60° was first found at the age of 12 in some soccer players and controls. A cam-type deformity defined by alpha angle was more prevalent in soccer players (26%) than in controls (18%), though not significantly when corrected for age (Figure 1).

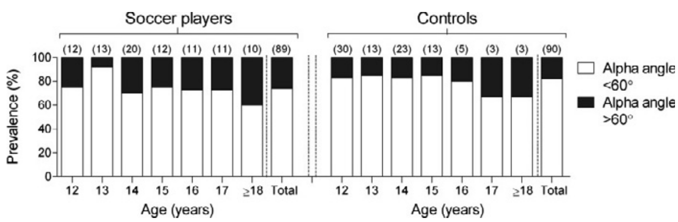

Fig. 1. The prevalence of a cam-type deformity (alpha angle >60°) per age in soccer players and controls. In both soccer players and controls an alpha angle >60° was found starting at the age of 12 years. Total number (n) per age is given on top of each bar.

The mean alpha angle in the soccer players was larger than in controls in both the Lauenstein view (50.8 vs 46.8, p = 0.002), and the AP view (50.9° vs 48.0° p = 0.079). A prominence in the anterosuperior head-neck junction was first found at the age of 13 years and the prevalence was 13.5% in the soccer players. No prominences were found in the controls. A flattening of the head-neck junction was also more frequently found in the soccer players (53% vs 19%, p = 0.0001) (Figure 2).

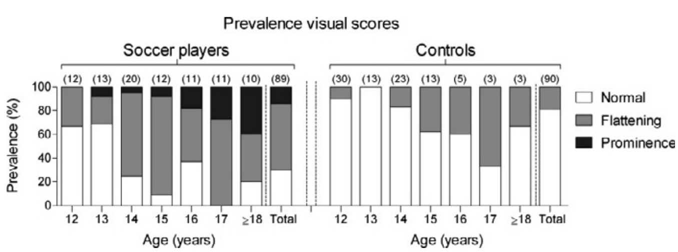

Fig. 2. Both a flattening and a prominence in the anterior head-neck junction were significantly more frequent in soccer players than in controls. Aspherical hips were especially found from the age of 14 years, starting with a flattening and with increasing age more prominences were found in the young soccer players.

Internal rotation was significantly reduced in soccer players with a cam-type deformity defined by alpha angle (19.7 vs 26.2, p = 0.002), whereas a positive impingement test did not associate with the presence of a cam-type deformity.

Conclusions: A cam-type deformity can be present and recognizable from the age of 13 years. Cam-type deformities are more prevalent, and more pronounced in young soccer players than in their non-athletic peers. This suggests that mechanical loads especially during the closure of the proximal femoral growth plate could be an important factor in the development of a cam-type deformity.

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TRABECULAR MORPHOLOGY IS ASSOCIATED WITH NUMEROUS PATIENT CHARACTERISTICS IN KNEES WITH OSTEOARTHRITIS: DATA FROM THE OSTEOARTHRITIS INITIATIVE (OAI)

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Purpose: Recent evidence suggests that peri-articular bone changes are integral to knee osteoarthritis (OA) pathophysiology. Peri-articular trabecular morphology changes have been associated with radiographic knee OA severity and may identify individuals at risk for knee OA progression. However, it is unclear how patient characteristics are associated with peri-articular trabecular morphology in knees with OA. The purpose of this study was to evaluate the association between patient characteristics and trabecular morphology in knees with OA.

Methods: The sample comprised a convenience sample of 337 participants in the Osteoarthritis Initiative (OAI) progression cohort who at the 30- or 36-month OAI visit had 3-tesla magnetic resonance imaging that included coronal 3D Fast Imaging with Steady State Precession (FISP) trabecular morphometry sequences. We used a trabecular morphometry program with a modified algorithm (calcDCN, University of California-San Francisco) to evaluate 4 peri-articular trabecular morphology measures: bone volume fraction (BVF), trabecular number (tb.n), spacing (tb.sp), and thickness (tb.th). The four measures were calculated for 20 consecutive central slices within a 15 mm x 3.75 mm region of interest placed in the peri-articular medial tibia and then averaged. Intra-tester reproducibility was high (ICC = 0.99). The association between demographic data or knee-specific data (from the 24-month OAI visit) and trabecular morphometry were evaluated with independent sample t-tests or Wilcoxon rank-sum tests (when applicable) and Spearman correlations. Among a subset of 285 patients with 24-month joint space narrowing (JSN) scores, four forward-selection multiple linear regression models were used to further evaluate the associations between patient characteristics and each trabecular morphometry measure.

Results: Participants were 66±9 years of age, body mass index 29.6±4.8 kg/m^2, and 50% female. Peri-articular trabecular morphometry was averaged (± standard deviation) for the cohort: BVF = 0.12±0.08, tb.sp = 1.53±1.25 mm, tb.n = 0.86±0.39 mm^{-1}, and tb.th = 0.13±0.03 mm. Peri-articular trabecular morphometry was not significantly different ($p > 0.05$) between participants with or without college degrees (n = 208, n = 127; respectively), with or without history of smoking (n = 147, n = 188; respectively), and with or without knee symptoms at the 24-month OAI visit (n = 191, n = 145; respectively). Many variables were associated with trabecular morphometry (see table). Age correlated with BVF (r = −0.16), tb.n (r = −0.18), and tb.sp (r = 0.17), but not tb.th (r = −0.08). Body mass index also correlated with BVF (r = 0.12), tb.n (r = 0.14), and tb.sp (r = −0.14), but not tb.th (r = 0.07). The 400-meter walk time (24-month visit) was related to tb.sp (r = 0.12). In multiple linear regression models, the presence of medial JSN and female gender were associated with all 4 trabecular morphometry measures. Three patient characteristics were associated with select measures: age (associated with tb.sp, tb.n), history of knee injury/surgery (associated with BVF, tb.th), and race (associated with tb.th).

Table. Characteristics Associated with Peri-articular Trabecular Morphology

	Mean Bone Volume Fraction	Mean Trabecular Spacing (mm)	Mean Trabecular Number (mm^{-1})	Mean Trabecular Thickness (mm)
Sex: Male (n = 169)	0.14 ± 0.09*	1.12 ± 0.71*	1.01 ± 0.38*	0.13 ± 0.03*
Sex: Female (n = 168)	0.10 ± 0.06*	1.94 ± 1.52*	0.71 ± 0.34*	0.12 ± 0.02*
Income: < $50K (n = 127)	0.11 ± 0.08	1.72 ± 1.48*	0.79 ± 0.38*	0.13 ± 0.02
Income: > $50K (n = 202)	0.13 ± 0.08	1.41 ± 1.08*	0.90 ± 0.39*	0.13 ± 0.03
Hx Knee Injury/Surgery: No (n = 203)	0.11 ± 0.07*	1.62 ± 1.31*	0.81 ± 0.36*	0.13 ± 0.02*
Hx Knee Injury/Surgery: Yes (n = 134)	0.14 ± 0.09*	1.39 ± 1.14*	0.94 ± 0.42*	0.13 ± 0.03*
Racial Background: Caucasian (n = 265)	0.12 ± 0.08	1.47 ± 1.20	0.87 ± 0.39	0.13 ± 0.03*
Racial Background: Other (n = 72)	0.11 ± 0.07	1.73 ± 1.41	0.80 ± 0.39	0.12 ± 0.02*
Medial JSN: No (n = 126)	0.09 ± 0.05*	1.77 ± 1.40*	0.73± 0.31*	0.12 ± 0.01*
Medial JSN: Yes (n = 159)	0.14 ± 0.09*	1.34 ± 1.06*	0.94 ± 0.40*	0.13 ± 0.03*
Lateral JSN: No (n = 241)	0.12 ± 0.08*	1.43 ± 1.20*	0.88 ± 0.37*	0.13 ± 0.03*
Lateral JSN: Yes (n = 43)	0.08 ± 0.06*	2.07 ± 1.37*	0.67 ± 0.36*	0.12 ± 0.01*

All values mean ± standard deviation. * indicates comparisons statistically significant ($p < 0.05$). JSN = joint space narrowing, Hx = history

Conclusion: Among participants with knee OA, gender, age, body mass index, history of knee injury/surgery, race, income, medial JSN, and lateral JSN were associated with medial tibia peri-articular trabecular morphology.

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MRI-BASED CARTILAGE THICKNESS LOSS AND JOINT SPACE NARROWING IN AN OAI CORE PROGRESSION SAMPLE, AND THEIR RELATIONSHIP WITH AGE, SEX, AND BMI

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Purpose: The aim of this study was 1) To determine the most sensitive measurement location in fixed flexion radiographs (JSW) and MRI (cartilage thickness; ThC), over 2 years, in a core sample of the OAI progression cohort; 2) To evaluate age, sex, and BMI as independent risk factors of structural progression at these locations.

Methods: One knee in each of 541 (224 men) OAI participants enrolled in the progression cohort was studied (all had frequent knee pain; 249 had KL Grade 2; 292 had KL Grade 3). Change in medial femorotibial JSW was measured automatically at 7 locations (fixed distances, FD) from PA fixed flexion radiographs, and change in ThC was measured in 16 femorotibial subregions after manually segmenting sagittal DESS images. The standardized response means (SRM) were used to determine the most sensitive measurement locations. Results were compared between men and women, and between the highest vs. lowest tertiles of age and BMI using t-tests, and general linear models with adjustment for the other variables. Beta coefficients (with 95% CI) and standardized beta (Z-scores) are presented.

Results: In this OAI core sample, the FD 0.225 JSW location was the most sensitive X-ray measure (SRM = 0.40), and the central medial femoro-tibial compartment subregion (cMFTC.ThC) the most sensitive MRI measure for structural progression over two years (SRM = 0.48). Age tertiles studied were 66–79 yrs, vs. 45–56 yrs, and BMI tertiles 31.8–47.7 kg/m2 vs.18.2–27.7. Age, sex, and BMI explained only 2.6% of the variation in structural progression (R2 of adjusted model) in X-ray and 3.9% in MRI. With X-ray, BMI ($\beta = -0.198$ mm, 95% CI −0.333, −0.064, standard $\beta = -0.308$) had a significant relationship with progression (Fig. 1), but neither age (adjusted p = 0.587) nor sex (p = 0.099) did. With MRI, high BMI ($\beta = -0.092$ mm, 95% CI −0.161, −0.023, standard $\beta = -0.278$), high age ($\beta = -0.090$ mm, 95% CI −0.159, −0.021, standard $\beta = -0.270$) and male sex ($\beta = -0.099$ mm, 95% CI −0.156, −0.042, standard $\beta = -0.299$) were all identified as significant risk factors for structural progression (Fig. 1).

Conclusions: Measurement locations in the central aspect of the medial femorotibial compartment were most sensitive to structural progression for both imaging methodologies, with MRI providing slightly greater sensitivity to change than fixed flexion radiographs over 2 years. Age, sex, and BMI explained <4% of the variation in structural progression with both methodologies. All were significantly associated with progression as measured with MRI (where men surprisingly showed greater progression than women) while only BMI was associated with progression as measured by X-ray. Our data suggest that MRI may be more sensitive for identifying progression of medial compartment knee OA than plain radiographs.

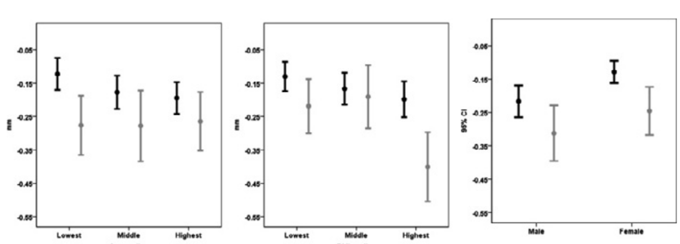

Fig. 1. Mean change (mm) of the most sensitive X-ray location (grey) and MRI (black) for tertiles of age (left) and BMI tertiles (middle) and sex (right). Error bars display the 95% confidence intervals.